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ABSTRACT

The purposes of this study were to determine whether mathematically gifted boys and girls in secondary schools were significantly different in cognitive abilities and personality factors and to determine whether these cognitive abilities and personality factors were accurate predictors of mathematical achievement. Mathematically gifted boys (n=77) and girls (n=62) who enrolled in two summers of an accelerated mathematics program completed a mathematics reasoning test (SAT-M), a verbal reasoning test (SAT-V), a measure of spatial ability (Group Embedded Figures Test), and a Personality Test (California Psychological Inventory). At the end of each summer program, students received mathematics achievement ratings depending on the number of courses completed. The only significant difference found indicated that boys have higher mathematical reasoning ability than girls. Also, mathematical reasoning ability was determined to be the single best predictor of mathematical achievement for the mathematically gifted boys, while verbal ability was the best predictor of mathematical achievement for the girls. For both the girls and the boys, neither spatial reasoning ability nor personality factors significantly predicted mathematical achievement. (Author)

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Cognitive Abilities, Personality and
Gender Differences in Math Achievement of Gifted Adolescents

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Abstract

The purposes of this study were to determine whether mathematically gifted boys and girls were significantly different in cognitive abilities and personality factors and to determine whether these cognitive abilities and personality factors were accurate predictors of mathematical achievement.

Mathematically gifted boys ($n = 77$) and girls ($n = 62$) who enrolled in two summers of an accelerated mathematics program completed a mathematics reasoning test (SAT-M), a verbal reasoning test (SAT-V), a measure of spatial ability (Group Embedded Figures Test), and a Personality Test (California Psychological Inventory). At the end of each summer program, students received mathematics achievement ratings depending on the number of courses completed.

The only significant difference found indicated that boys have higher mathematical reasoning ability than girls. Also, mathematical reasoning ability was determined to be the single best predictor of mathematical achievement for the mathematically gifted boys. While verbal ability was the best predictor of mathematical achievement for the girls. For both the girls and the boys, neither spatial reasoning ability nor personality factors significantly predicted mathematical achievement.

"Overall the evidence pointing to a decline in the cognitive achievement of American high school students in the last two decades is conclusive, and relatively few Americans remain aware of that fact" (Lerner, 1982, p. 70). Even more disconcerting to educators and social scientists might be the fact that two subgroups of American society which have been the focus of increased national concern, the highly able student and the female student, have had the greatest decline in Scholastic Aptitude Test (SAT) scores. For example, the disparity between males and females on the SAT has been increasing in both the verbal and math subtests (Benbow and Stanley, 1982). By 1980, the average male taking the SAT had a verbal score of 428 while the average female had a score of 420. Prior to 1972, females had scored consistently higher than males. On the mathematical section of the SAT, males averaged 491 as contrasted to the female's average of 443.

Reporting on data from their longitudinal study of gifted seventh and eighth graders, Benbow and Stanley (1980) hypothesized that these sex differences indicate higher mathematical reasoning ability for males. Other researchers, who attempted to look solely at environmental etiologies, attributed the gap to social conditioning, differences in test content, test-taking strategies (Sherman, 1981), and/or differential course taking (Pallas and Alexander, 1983). Before the battle lines become hardened into a nature-nurture dichotomy perhaps a more fruitful approach to this important issue would be to explore further the variables that are associated with mathematical achievement. Such variables would include spatial ability, mathematical reasoning, verbal reasoning and personality factors.

In order to avoid a debate over terminology (Benbow and Stanley, 1983; Alexander and Pallas, 1983), it should be pointed out that the terms "reasoning ability" and "aptitude" will be used interchangeably.

Investigators have demonstrated that mathematical aptitude and verbal aptitude are related to mathematical achievement (Bennett, Seashore, & Wesman, 1974). Also, sex differences have been widely reported in mathematical aptitude, verbal aptitude and mathematical achievement (Very, 1967; Maccoby and Jacklin, 1974). Males outperform females in mathematical achievement and mathematical aptitude. Males also have more specialized factorial structures in mathematical aptitude. Females outperform males in verbal aptitude and have more specialized factorial structures in verbal aptitude. Some researchers believe that these sex differences in mathematics are an artifact of differential course taking and differential attitudes toward mathematics (Fennema, 1980; Pallas and Alexander, 1983), however, for mathematically gifted seventh and eighth graders these hypotheses are not true (Benbow and Stanley 1980). Mathematically gifted seventh and eight-grade boys and girls have similar attitudes toward mathematics and similar mathematical course-taking behavior. Although there are not significant differences in their verbal aptitude, boys have significantly higher mathematical aptitude than girls (Benbow and Stanley 1980). It is not known how these aptitude differences relate to mathematics achievement for mathematically gifted seventh and eight-grade boys and girls and whether these boys and girls use these aptitudes differentially for mathematical achievement.

Spatial ability with some exceptions has also been characterized as being important for mathematical achievement (Hills, 1957; Hessman, 1976). At the onset of puberty, males have demonstrated significantly higher spatial skills than women (Maccoby and Jacklin, 1974). Also, spatial skills may be more important to mathematical achievement for females than males (Sherman, 1981). For the gifted, it has been suggested that spatial skills may help explain the

sex difference in mathematical aptitude and achievement (Benbow and Stanley, 1980). With a small sample of mathematically gifted boys and girls, no sex differences were found in spatial visualization skills (Becker, 1978). What is not known is whether sex differences exist in spatial visualization and spatial orientation skills, and to what extent spatial abilities are reliable in the prediction of mathematical achievement for gifted boys and for gifted girls.

Another variable of interest has been personality. Above and beyond cognitive abilities, personality has been shown to be an important predictor of mathematical achievement (Gough, 1964). For both high ability IQ groups and mathematically gifted groups, males and females have similar personality profiles; they are more socially mature, better adjusted, and more motivated than their nongifted agemates (Haier and Denham, 1976). No evidence exists, however, on sex differences in personality factors for a large sample of mathematically gifted adolescents. Also, no one has explored whether certain personality factors are more important above and beyond cognitive abilities for the mathematical achievement of mathematically gifted boys or girls. In order to address the issues raised above, the following hypothesis were formulated:

- H₁: Mathematically gifted boys will have significantly higher mathematics reasoning ability than mathematically gifted girls.
- H₂: There will be no significant differences in verbal reasoning ability for mathematically gifted boys and girls.
- H₃: There will be no significant differences in spatial ability for mathematically gifted boys and girls.
- H₄: There will be no significant differences in the personality factors of mathematically gifted boys and girls.
- H₅: Mathematical reasoning ability, verbal reasoning ability, spatial ability, and personality factors will differentially predict mathematical achievement of mathematically gifted boys and girls.

Methods

Setting and Subjects

One hundred and thirty nine seventh and eighth grade mathematically gifted boys ($n = 77$) and girls ($n = 62$), who were attending one of two summers of the Project for the Study of Academic Precocity (PSAP), volunteered to participate in this study. Offered at Arizona State University, the PSAP provides an opportunity for students who are highly able in mathematical and/or verbal reasoning ability to be recognized and assisted in their educational development. The PSAP follows the "3-D Model" to assist these gifted youth. The three phases of this model are Discovering, Describing, and Developing.

The first phase, the Discovering phase, involves two steps. In the first step, students who score in the top stanine (96 percentile or better) according to national norms on an age appropriate, standardized test of mathematical reasoning ability are invited to take the Scholastic Aptitude Test (SAT). The second step involves targeting for program entry those students who score above 400 on the math reasoning section of the SAT, or who are unusually motivated to achieve in mathematics.

The second phase, the Describing phase, involves the gathering of information concerning the student's other talent areas which might be helpful in academic counseling. Standardized testing with such tests as the Differential Aptitude Test might be employed to determine the skill development of the student in appropriate subject areas.

The third phase, the Developing phase, emphasizes accelerative coursework. Enriched curricula and academic counseling are also utilized.

Criterion Variable

The criterion variable was mathematics achievement. This continuous variable was measured by the number of courses that a student passed in the

Cooperative Mathematics Achievement Test series. The Cooperative Mathematics Achievement Test series was developed by The Education Testing Service and was designed to measure precalculus mathematics skills. A passing grade was defined as any score at or above the 85th percentile on this standardized test, however, students still received a percentage of a course number depending on their test score. A student could have scored anywhere from zero to five on this variable.

Dependent and Predictor Variables

There were five dependent/predictor variables in this study, three aptitude variables and two personality factors. Mathematics reasoning ability, verbal reasoning ability, and spatial orientation composed the aptitude variables. The two personality variables, (a) Social Confidence and Drive and (b) General Adjustment, were determined by a varimax rotation of the 18 scales of the California Psychological Inventory. This factor analysis yielded these two relatively independent factors which have high reliability.

During the second summer PSAP, another measure of spatial ability was also obtained. This was a measure of spatial visualization. Both spatial orientation and spatial visualization are components of spatial ability.

Instrumentation

Four instruments were utilized in this study. The Scholastic Aptitude Test (SAT), the Group Embedded Figures Test (GEFT), and the Differential Aptitude Test (DAT) measured cognitive abilities, and the California Personality Inventory (CPI) measured personality factors.

Scholastic Aptitude Test. The Scholastic Aptitude Test (SAT) is a multiple-choice test designed for college bound juniors and seniors in high school. Buros (1965) reports that the test is essentially a power test with speed accounting for a small percentage of the testing performance. The SAT

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has two independent subtests which assess mathematical reasoning ability (SAT-M) and verbal reasoning ability (SAT-V). The mathematics reasoning test is composed of 60 questions which assess arithmetic reasoning, algebra, and geometry. The verbal reasoning section has 85 questions which measure vocabulary and comprehension of written materials. The specific content of this section tests ability with antonyms, sentence completions, analogies, and reading passages.

Ranging from 200 - 800, the scores are based on the April 1941 national test administration of the SAT. Each new version of the test is linked to previous editions of the test and to the base test by an elaborate procedure of sampling items from year to year. Since all tests are anchored to the 1941 test, the mean scores for both math and verbal reasoning abilities currently are below 500, and the standard deviations are above 100 which were the original means and standard deviations.

For the 1982 SAT, internal consistency reliability estimates were obtained from the Kuder Richardson-20, using the Dressal Adaptation procedure. The internal consistency score for the verbal section is .91 and for the mathematics section is .90. The standard error of measurement for the verbal section is 33 points and for the mathematics section 36 points.

The intercorrelation between the two mathematics sections is .81, and the intercorrelation between the two verbal sections is .83. The verbal and math sections have a .67 intercorrelation coefficient with each other.

The type of validity which is most relevant for use of the SAT is predictive validity. Predictive validity is the ability of a test to predict some future performance or behavior. In this case, future behavior is assessed as the grade point average obtained during the freshman year of college. The validity of using the SAT-Mathematics section for predicting grades in the

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freshman year is .33 for males and .26 for females. The validity of using the SAT-Verbal section for predicting grades of freshman in college is .35 for males and .36 for females.

Even though this test is designed primarily for high school juniors and seniors, Stanley (1974) reports that the test is appropriate for mathematically gifted boys and girls and has good predictive validity for this population.

Group Embedded Figures Test. The construct of field independence-dependence cognitive styles grew out of Witkin's research into psychological differentiation (Witkin, Oltman, Raskin, & Karp, 1971). A field independent person relies on him/herself as a referent for behavior while a field dependent person relies on the field outside of him/herself.

The GEFT purports to measure the field independence-field dependence continuum, a cognitive style dimension. Designed for group administration, the GEFT consists of 25 complex test figures, 18 of which are the actual test while the initial seven are practice figures. Within a limited time period, subjects are required to find and to trace a simple target form embedded within a more complex geometric figure. A score could range from zero to 18 depending on the number of figures correctly traced.

The internal consistency reliability of the GEFT appears adequate with a correlation of .82 reported between the second and third sections as corrected for by the Spearman Brown formula (Witkin et al., 1971). Buros (1965) reports acceptable construct validity for the GEFT on the dimensions of field independence - field dependence.

To answer the questions of interest, the GEFT was utilized as an example of spatial orientation (McGee, 1979; Harris, 1978; Sherman, 1967). This use has validity in that factor analytic studies have indicated that tests of spatial abilities and the field dependence-independence tests merge together in a

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factor that is similar in its description to the Spatial Orientation factor (McGee, 1979).

Differential Aptitude Test - Spatial Relations. The Differential Aptitude Test (DAT) is one of the most widely used multiple aptitude batteries. It was designed for use in the educational and vocational counseling of students who are in grades 8 through 12 (Anastasi, 1982). The norming process involved over 64,000 students from 75 schools.

The Spatial Relations section of the DAT (DAT-SR) is one of eight tests that make up the battery. Students have 25 minutes to complete the Spatial Relations section which involves the ability to manipulate objects mentally by imagining how an object would look if made from a specific pattern or how it would look if rotated in a certain way. The maximum raw score is 60.

At each grade level, from grades 8 to 12, reliability coefficients were calculated separately for each sex and form of the test (forms S and T). The reliability coefficients were split half coefficients and were corrected by the Spearman-Brown formula to reflect the reliability of the entire test (Bennett, Seashore, and Wesman, 1974). The reliability coefficients of the spatial relations section range from .90 to .95 for boys across all the grade levels and range from .89 to .94 for girls across grade levels. The median standard error of measurement for both boys and girls is approximately 3.2.

There is a plethora of validity data on the DAT with several thousand validity coefficients gathered by 1982 (Anastasi, 1982). For example, there exists a .27 correlation between the Spatial Relations test and course grades in mathematics for boys. This median correlation was gathered on over 40 studies. For girls the median correlation is .31. Bennett et al. (1974) report that the Spatial Relations section may be a good predictor of art course grades, and drafting grades for boys, and data processing grades for girls.

California Personality Inventory (CPI). A self-administered personality test designed for group administration, the CPI is a measure of personality assessment for normal functioning people. Anastasi (1982) states that the CPI is "one of the best personality inventories currently available" noting that "its technical development is of a high order, and it has been subjected to extensive research and continuous improvement" (p. 508).

The CPI has been normed on over 6000 men and 7000 women, short term test-retest coefficients are fairly high with a range of .71 to .90 while long-term coefficients reflect moderate stability with a .60 to .70 range (Anastasi, 1982). Also, the CPI has been subjected to extensive research which has resulted in copious validity data.

The CPI seems to be an appropriate tool for assessing personality characteristics of gifted seventh and eighth graders. Megargee (1972) indicates that the CPI can be accurately used with younger samples, and norms have been established with a sample of gifted eighth graders (Lessinger & Martinson, 1961) and with seventh and eighth grade mathematically gifted boys and girls (Weiss et al., 1974; Haier & Denham, 1976).

Procedures

All students who were enrolled in PSAP math classes completed the SAT mathematics and verbal sections subsequent to admission to the PSAP program. Students who volunteered to be involved in this study also completed the GEFT and the CPI at another testing time. The GEFT was administered first and the CPI second. The DAT was also administered during the second summer of the study. Testing took place in a large classroom over a three hour period. Students took the tests during one of three testing sessions established during a one week period which occurred during the third week of each six week PSAP program.

At the end of the PSAP program, the criterion variable, mathematics achievement, was obtained for each subject. The criterion variable was the number and/or portions of math courses passed during the summer program.

Factor Analysis of the CPI

Extensive research on the CPI has shown that the 18 personality scales are highly intercorrelated (Megarge, 1972). Therefore, it was necessary to correct for the intercorrelations through use of factor analysis. "Given an array of correlation coefficients for a set of variables, factor-analytic techniques enable us to see whether some underlying pattern of relationships exists such that the data may be rearranged or reduced to a smaller set of factors or components that may be taken as source variables accounting for the observed inter-relations in the data" (Kim, 1975, p. 469).

Data from summer one and summer two were factor analyzed separately to ensure that the same factorizations existed for both groups of subjects. Both factor analyses returned five eigenvalues greater than one for the preliminary principal components with unities as initial communality estimates. For Cattell's (1966) scree test (Figure 1) the plot of eigenvalues leveled off for the fourth and subsequent eigenvalues, thus 3 factors were retained for the principal factor solution in each set of data. Communalities were iterated until converged. The three factors accounted for 31, 20, and 13 percent of the total variance and 48, 30 and 22 percent of the common variance for summer one. In summer two, the three factors accounted for 36, 18, and 10 percent of the total variance and 56, 28, and 15 percent of the common variance. The factor matrices were rotated by Kaiser's varimax into simple structure and resulting factor loadings are reported in Table 1.

As can be seen in Table 1, there are two primary factors for summer one and for summer two. Factor one is composed of nine CPI scales having a factor

loading above .57 in summer one and above .46 in summer two. These scales were summoned to form a factor which appears to measure General Adjustment. Factor two, a linear combination of five scales which had a factor loading of .52 or greater in summer one and of .75 or greater in summer two, appears to measure Social Confidence and Drive. Together these two factors account for 51 percent and 54 percent of the total variance in the summer one and summer two data, respectively. Since these two factors were consistent across summers and were consistent with other factorizations of the CPI (Megargee, 1972), they were the two factors investigated.

Results

The purpose of this study was to determine whether mathematically gifted boys and girls differ in their mathematical reasoning ability (H_1), in their verbal reasoning ability (H_2), in their spatial ability (H_3), and in their personality factors (H_4). Additionally, this study examined whether these variables would differentially predict mathematics achievement for mathematically gifted boys and girls (H_5).

Prior to testing these hypotheses, a MANOVA, testing for differences between the boys and girls, and a discriminant analysis were conducted on the data from the second summer subjects to determine whether spatial visualization (DAT-SR) was a significant dependent variable. The MANOVA approached significance, $F(6, 62) = 2.12$, $p < .06$, and the discriminant analysis revealed that spatial visualization made the weakest contribution (SDF, standardized discriminant function = .25) to the variance between boys and girls. Therefore, this variable was dropped from the study and the other five dependent variables were used to analyze the hypotheses across all subjects.

To test for differences between boys and girls, hypotheses one through four, a MANOVA was conducted and found to be highly significant, $F(5, 131) =$

5.29, $p < .0001$. A discriminant analysis revealed that mathematical reasoning ability (SDF = 1.05) was the major variable discriminating between boys and girls. A one way ANOVA using math ability as the dependent variable was also highly significant, $F(1,135) = 7.42$, $p < .007$. The means, presented in Table 2, show a 39 point difference which favors the boys ($\bar{x} = 525.9$) over the girls ($\bar{x} = 487.2$). These results support hypothesis one: Mathematically gifted boys will have significantly higher mathematical reasoning ability than mathematically gifted girls.

Hypothesis two predicted no significant differences in verbal reasoning for mathematically gifted boys and girls. Examination of the discriminant analysis results revealed that SAT-V (SDF = -.68) was a relatively strong discriminating variable between the boys and girls; however, the one way ANOVA using verbal reasoning ability as a dependent variable was not significant, $F(1,135) = .85$, $p < .36$. Therefore, the 16 point difference in SAT-V scores which favored the girls ($\bar{x} = 456$) over the boys ($\bar{x} = 440$) was not significant. The null form of hypothesis two was accepted.

Examination of the discriminant analysis results for spatial ability, using the spatial orientation measure, revealed that it had only a moderate discriminating power (SDF = -.48). Additionally, the ANOVA was not significant, $F(1,135) = 2.14$, $p < .15$. Therefore, hypothesis three which predicted no differences between mathematically gifted boys and girls in spatial ability was accepted.

The standardized discriminant function coefficients for General Adjustment (SDF = -.28) and for Social Confidence and Drive (SDF = .44) indicated that each of these two personality factors contributed negligibly to the multivariate difference between boys and girls. Also, the one-way ANOVA's for

Social Confidence and Drive, $F(1,135) = 2.14$, $p < .15$ and for General Adjustment, $F(1,135) = 1.78$, $p < .18$, were nonsignificant. Therefore the null form of hypothesis four was accepted. There are no significant differences in the personality factors of mathematically gifted boys and girls.

Stepwise multiple regressions were used to test whether mathematical ability, verbal ability, spatial ability, General Adjustment, and Social Confidence and Drive differentially predict the mathematical achievement of boys and of girls (H_5). For boys math ability was the primary predictor of mathematics achievement with the multiple coefficient of correlation R equal to .50. This accounted for 25 percent of the variance in the boys' mathematical achievement scores. Verbal reasoning ability, which had a high correlation with math ability ($r = .40$), a low correlation with mathematics achievement ($r = .01$), and a negative beta weight ($-.23$), functioned as a suppressor variable and added only five percent to the accounted for variance in boys' mathematical achievement scores. Spatial Ability, General Adjustment, and Social Confidence and Drive contributed only two percent more to the explained variance in boys' mathematical achievement scores.

For girls, verbal ability was the primary predictor of mathematical achievement. The multiple coefficient of correlation R for the girls was equal to .38 which accounted for 15 percent of the explained variance. Together, the other four variables--Mathematical Abilities, Spatial Ability, General Adjustment, and Social Confidence and Drive--accounted for only 4 percent more of the variance in girls' achievement scores.

Since stepwise regression controls for the effects of one variable before entering a second, it is useful to examine the relative contributions of the beta weights of the two best predictors for both boys and girls. This can be

accomplished by using the fundamental equation of multiple correlation (Cooley & Lohnes, 1971), which specifies that the inverse of the intercorrelations of predictors (R_{pp}^{-1}) postmultiplied by the column vector of predictor - criterion correlations (R_{cp}) yields the coefficients b for the standardized regression function, $R_{pp}^{-1} R_{cp} = b$. For boys the standardized regression weights after utilizing this formula are .495 for math reasoning ability and .0001 for verbal reasoning ability. So the stepwise and fundamental equations are essentially the same for boys. For girls the beta weights are .227 for mathematics reasoning ability and .227 for verbal reasoning ability so that both variables share the predictive ability. Therefore, both math reasoning ability and verbal reasoning ability share the explained variance for the prediction of math achievement of girls.

For boys, the single most significant predictor of mathematical achievement was math reasoning ability, and for girls the prediction was equally shared by math and verbal reasoning abilities. Therefore, hypothesis five was accepted.

Discussion

Hypothesis one which predicted that mathematically gifted boys would have significantly higher mathematical reasoning ability than mathematically gifted girls was supported. This finding is in accord with crosscultural studies of 12 other nations (Husen, 1967), with results of numerous studies conducted in the United States (Very, 1967; Backman, 1972; Wise, Steel & MacDonald, 1979; Maceoby & Jacklin, 1974), and with results obtained in a study of over 10,000 mathematically gifted boys and girls (Benbow & Stanley, 1980).

Although not directly investigated, it is interesting to note the mathematical reasoning ability distributions for boys and girls within this sample. The ratio of boys to girls scoring at or above 500 on the SAT-M was 2.1:1. The ratio of boys to girls scoring at or above 600 was 3.5:1. In

contrast, there were 1.2 boys for every girl in this sample. Therefore, there is not just a difference between means (boys = 525.9 and girls = 487.2), but more boys (than girls) are scoring in the upper levels of SAT-M. Not only are boys more able in math reasoning, but there are more boys than girls who demonstrate superior math reasoning ability. These dual findings are consistent with the findings and conclusions of Benbow & Stanley's (1980) research.

These findings indicate that investigators cannot ignore the biological explanation of gender differences in mathematical reasoning ability. Further, this research finding challenges Hyde's (1981) conclusion that gender differences are very small and therefore must be interpreted with caution. For this sample of students, there was a very strong gender difference.

These data also challenge the theory of differential coursework being the major contributor to gender difference in mathematical reasoning ability (Fennema, 1980; Armstrong, 1979; Pallas & Alexander, 1983; deWolf, 1981). Fennema and Sherman (1977) have maintained that when the amount of course work is controlled, gender differences disappear. Their research has supported their belief; however, the major difference between their research and the research of Benbow and Stanley (1980) and this study is the measure employed. Fennema and Sherman (1977, 1978) examined math achievement, while this research and that of Benbow and Stanley (1980) employed a measure of mathematical reasoning ability. While there are overlapping components, ability and achievement are not the same. Ability may influence coursework selected, and therefore, there would be coursework differences; however, coursework does not influence ability. It does influence achievement.

Researchers must be open to other explanations, both biological and sociocultural, for these differences. Educators must be aware of these differences and concern themselves not so much with the "why" but with developing

effective teaching strategies to enhance the skills of both boys and girls equally. Therefore, if there is in fact a deficit of skills on the part of the girls in mathematical reasoning ability, it might be more reasonable to search for strategies to deal with it rather than finding alternative hypotheses to explain it away.

Hypothesis two predicted that there would be no significant differences in verbal reasoning ability between mathematically gifted boys and girls. This hypothesis was supported. Contrary to other research indicating that females are generally superior to males on measures of verbal ability before age three and after age eleven (Maccoby & Jacklin, 1974; Parsons, 1980), there were no sex differences in verbal ability for this sample of gifted youth. Analyses revealed that though girls had a slight advantage of 16 points in verbal reasoning ability, verbal ability did not discriminate strongly between the boys and girls. This finding is compatible with the results of Benbow and Stanley (1980) who found that for six separate SMPY talent searches, the boys and girls performed equally well in verbal reasoning ability. It should be noted that the means for the boys and girls in this study exceeded the 1980 means for average 12th grade boys and girls taking the SAT-V test; therefore, these boys and girls are highly able in verbal reasoning ability, but not different from each other.

Though not directly investigated, it is interesting to examine the correlations of verbal reasoning ability of both boys and girls with the criterion, mathematics achievement. The verbal ability of boys did not correlate with mathematics achievement ($r = .01$). The girls' verbal ability had a moderately strong correlation with mathematical achievement ($r = .38$). These findings seem to indicate that even though there were no significant differences between boys and girls in verbal reasoning ability, verbal ability may be related to girls' mathematical achievement.

Sherman's (1978) "bent twig" theory may help to explain these correlations. According to this theory, the often noted finding of female verbal precocity may predispose the girls to a left brain, verbally mediated approach to problem solving. Additionally, this theory utilizes the law of primacy which states that that which is established initially becomes the most firmly set. Applied to this research, the "bent twig" theory would suggest that girls may be predisposed to utilizing verbal problem solving both earlier in life and more often in life than do boys. Therefore, the verbal component would become an integral facet of their cognitive abilities whereas this is not necessarily true for boys. As Sherman (1978) concluded, ". . . verbal skills may be sex preferred for more females than males" (p. 172-173). Her hypothesis is supported by the findings of this research.

There were no significant differences in spatial ability for these gifted adolescents (H). These results are contrary to the findings of most other researchers studying nongifted populations. Harris (1978) Droege (1967), Hobson (1947), Bieri, Bradburn, Galinsky (1958), Witkin et al. (1954) and Maccoby and Jacklin (1974) all found that males were superior to females in spatial ability and that this finding was the most persistent gender difference in cognitive abilities. However, the results from the present study are consistent with the few studies of spatial ability for mathematically gifted adolescents. Although Benbow and Stanley (1980) favored the hypothesis that males' advantage in spatial ability may account for their superior mathematical ability, the limited studies on the spatial ability of mathematically gifted students have reported no gender differences (Fox, 1974; Becker, 1978). Fox conducted her research on a very small sample of students; however, Becker's subjects were 227 students who participated in the 1976 Johns' Hopkins Talent Search. She administered only a spatial visualization test and discovered that

there were no significant differences between the sexes. The findings of this study support Becker's conclusions and extend the ramifications of no significant gender differences in spatial ability to a second component of spatial ability, spatial orientation. Overall evidence suggests that the hypothesis that girls reason less well mathematically because of a deficit in spatial skills may not hold for mathematically able youth.

Testing hypothesis four, all analyses disclosed that mathematically gifted boys and girls were remarkably similar in their General Adjustment and in their Social Confidence and Drive. Congruent with other literature that reports few if any gender differences in personality traits for high ability groups (Davids, 1966) and in personality traits for the mathematically gifted (Haier & Denham, 1976), this research confirmed these findings using clearly defined and independent personality factors.

This finding may be attributed to either of two explanations. One explanation is that mathematically gifted girls possess a more androgynous personality pattern than other females (Callahan, 1979). Potter (cited in Tobias, 1978) reported that college women who had high math ability described themselves as more androgynous than did college women who had high verbal ability or women who had both high verbal and math ability.

The second explanation is an extension of the first in that both boys and girls may possess cross-sex personality characteristics which provide an intellectual advantage for both genders (Mills, 1978). These mathematically gifted boys and girls exhibit traits that seem to embody the most advantageous combination of traits that are typically identified as being either male or female. This combination seems to enhance the social and intellectual functioning of this sample.

In testing hypothesis five, it was found that the boys' prediction equation was different from the girls and more powerful than the girls. For boys, mathematical reasoning ability was the best predictor of mathematical achievement accounting for 25 percent of the variance. For boys only, this result supports Stanley's (1977) contention that it is "evident" that the SAT-M is a powerful predictor of the success of 12 and 13 year old youth who are accelerated educationally. In addition, in this study verbal reasoning ability functioned as a suppressor variable for the boys. Verbal ability accounted for another five percent of the explained variance. This finding may support another contention of Stanley (1977) that the SAT-V, a measure of verbal reasoning ability, may be related to the speed of thinking and of taking tests. If this is true, by verbal ability acting as a suppressor variable in the boys' prediction equation, it is actually removing the influence of the speed of thinking and of taking tests and, therefore, improving prediction.

For girls, this research indicated that verbal ability was the best predictor of mathematical achievement, accounting for 15 percent of the explained variance. The addition of mathematical ability into the predictor equation only added two percent to the predictor equation. Because of the shared variance between these two predictors, however, both shared the prediction according to the fundamental equation of correlation. Therefore, for girls, Stanley's first contention that the SAT-M is a powerful predictor of the success of 12 and 13 year old youth who are accelerated educationally does not seem to be applicable. Also, his second contention that the SAT-V is related to the speed of thinking and of taking tests does not seem to be true for the girls in this study. In fact, verbal ability was the major predictor of mathematical achievement for girls, even though its predictive power was much smaller than was the power of math ability for boys.

The results of this research validate similar findings by Benbow and Stanley (1982) and factorial studies that have shown that girls may have less well developed mathematical reasoning ability (Blackwell, 1940; Rusch, 1957; Filella, 1960; Guthrie, 1963; Very, 1967). For girls, verbal reasoning ability is important for math achievement.

If this is true, then educators need to pay more attention to cognitive style differences. Females may need to approach mathematics differently than males to be successful. This might include using text books that place more emphasis on a conceptual approach which explains all the steps of the process, instead of the usual approach of deriving equations with gaps in the logical process by statements such as "as is evident" or "as it can be clearly seen."

Another approach educators might consider is to provide remediation to females by instructing them in the use of other cognitive styles that utilize formal mathematical processes. Behavioral theory states that behavior can be learned and unlearned, and that through instruction, modeling, practice, and reinforcement, new behaviors can be acquired. Therefore, special classes could be developed which teach females to use more formal mathematical strategies for mathematical problem solving.

There are several limitations of this study which need to be mentioned. The subjects were nonrandom volunteers who were attending a unique, fast paced summer program. Therefore, generalizability to other youth is limited. Additionally, the test of math achievement may have favored boys over girls since research has shown that boys typically perform better on standardized achievement tests. That the DAT-SR was given to only half of the sample is another limitation.

Several issues for future research evolved from this study: (1) At what age level do gender differences in math reasoning ability first appear and what

are the social and environmental factors influencing this difference? ²² (2) Do these prediction equations have predictive validity across high school? (3) Does matching methods of information presentation with reasoning abilities enhance math achievement? and (4) To what extent does instruction in an alternative cognitive style influence math achievement?

In researchers' efforts to understand the factors that influence the mathematical achievement of mathematically gifted boys and girls, ability differences should not be ignored. But rather, efforts need to be made to foster intellectual development by effectively utilizing students' strengths, primarily mathematical reasoning ability for boys and verbal reasoning ability for girls.

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Table 1.

Rotated Factor Matrix
Describing Structures of CPI Scales

<u>Scales</u>	<u>Factor One</u>		<u>Factor Two</u>		<u>Factor Three</u>	
	Summer 1	Summer 2	Summer 1	Summer 2	Summer 1	Summer 2
Tolerance (TO)	.845	.853	.046	.178	-.127	-.057
Well Being (Wb)	.801	.819	.119	.247	.042	.051
Good Impression (Gi)	.758	.751	-.086	.037	.202	-.107
Self-Control (Sc)	.747	.824	-.499	-.323	.152	.164
Intellectual Efficiency (IE)	.741	.620	.304	.441	-.010	-.057
Responsibility (Re)	.732	.560	-.093	-.015	.338	.546
Achievement via Conformity (Ac)	.715	.716	-.004	.281	.353	.324
Achievement via Independence (Ai)	.708	.782	-.132	.141	-.413	-.330
Psychological Mindedness (Py)	.573	.464	.088	.381	-.434	.096
Sociability (Sy)	.033	.165	.882	.838	.084	.024
Self-acceptance (Sa)	-.106	.037	.855	.879	.020	.038
Social Presence (Sp)	.083	-.005	.774	.796	-.286	-.409
Dominance (Do)	.234	.040	.674	.762	.302	.388
Capacity for Status (Cs)	.510	.390	.527	.746	.307	-.164
Flexibility (Fx)	.075	.305	.031	.045	-.829	-.630
Communality (Cm)	.063	.055	.116	.401	.687	.539
Socialization (So)	.350	.204	-.155	.212	.596	.272
Femininity (Fe)	.075	.206	-.465	-.154	.023	.317

Table 2. Means and Standard Deviation on Cognitive, Personality, and Achievement Variables for Males and Females

Variable	Males		Females	
	M	SD	M	SD
Mathematics Ability	525.9	87.7	487.2	75.9
Verbal Ability	440.1	97.1	456.1	104.7
Spatial Orientation	13.6	3.9	14.5	3.6
Positive Adjustment	193.0	31.0	200.6	35.4
Social Confidence & Drive	131.4	18.7	126.2	22.8
Achievement	1.27	.62	1.16	.42

Spatial Visualization (Summer II only)	42.5	7.7	41.3	7.7

Figure 1

Cattell's Scree to Determine
CPI Factors retained for analysis

